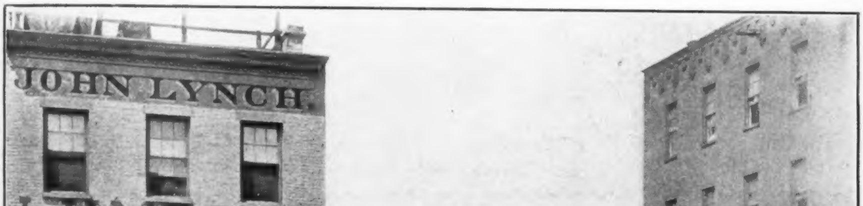
Compressed Air

DEVOTED TO THE USEFUL APPLICATION OF COMPRESSED AIR.

VOL. V. NEW YORK, SEPTEMBER, 1900. No. 7



THE NEW HARDIE AIR MOTOR,
ON THE METROPOLITAN STREET RAILWAY CARS, NEW YORK.

Compressed Air.

A MONTHLY PUBLICATION DEVOTED TO THE USEFUL APPLICATION OF COMPRESSED AIR.

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Subscription, including postage, United States, Canada and Mexico, $1.00 a year. All other countries, $1.50 a year. Single copies, 10 cents.

Advertising rates furnished on application.

We invite correspondence from engineers, contractors, inventors and others interested in compressed air.

All communications should be addressed to COMPRESSED AIR, 26 Cortlandt St., New York.

London Office, 114a Queen Victoria Street.

Those who fail to receive papers promptly will please notify us at once.

Entered as Second-Class Matter at the New York, N. Y. Post Office.

VOL. V. SEPTEMBER, 1900. NO. 7.

We publish on the cover of this issue an illustration of the new Hardie Compressed-Air Motor Car. In view of recent events on the 28th and 29th streets lines in New York City, this car is interesting in that it has recently been decided to substitute an improved form of the Hardie car for the experimental cars that have been removed from the 28th and 29th street lines. These Hardie cars are admitted to be the best in the line of pneumatic storage cars. They are built on the basis of a large experience in which Mr. Robert Hardie has been personally the active mechanical engineer, watching results and changing and simplifying the motor on lines of experience. This in itself should inspire confidence, but in addition we have the facts before us that the Hardie motor was in operation in New York for one year on 125th street, during which time a complete record was kept and this record is open for inspection. The work done was satisfactory to the officers of the Railroad Company, and to the thousands of patrons of the road who used them daily. It is a matter of note that, unlike the cars recently removed from the 28th and 29th streets lines, these cars on 125th street were so easy of movement that the general public were unconscious of the fact that they were being drawn by air as distinguished from any other form of motor. These motors were afterwards taken to Chicago, where they have been in daily operation for about fifteen months, and recently they have been purchased by the Chicago Company, the purchase comprising the entire plant, two cars and the air compressor. They are used in Chicago as "Owl cars," running at night on cable roads. During the severe snow storms of the past winter they ran satisfactorily. The work in operation now on the 28th and 29th streets line is to prepare the road bed for these cars. The old light rails that were used are being replaced by others sufficiently heavy to carry the air cars. It is but natural that an air car, or, in fact, any form of motor car, should be heavier than a horse car, but the Hardie air cars are lighter than the electric storage cars and compare favorably in weight with any other system of power traction. The Metropolitan Street Railway Company, of New York, has ordered twenty-eight of these cars for service on the streets and have placed with the Compressed Air Company, an additional order for one hundred air cars to be taken after the twenty-eigth have been put into operation as per agreement.

These facts are important to railroad men and engineers in that they indicate the practicability of using independent motors which are always appreciated because they are complete in themselves, carrying their own power, and can be readily removed from the track and taken to the shop, in this way avoiding interruption to the general traffic of the road.

With this number of "Compressed Air" Mr. Andrew E. Kenney retires from his position as Managing Editor of this paper. About five years ago, when the suggestion was made that a paper devoted exclusively to compressed air interests would find a field of usefulness, Mr. Kenney strongly urged the idea and took personal charge of the work. That he has done this diligently and successfully the paper itself bears evidence. Our circulation has steadily increased until at the present time we have on our subscription list names from all parts of the world, and the high class to which our advertising patrons belong is in itself an evidence that this publication has made a place for itself. We do not claim that "Compressed Air" has yet reached the point where it brings good financial results. This is because the field is necessarily limited and the expenses of preparing and publishing a paper of this kind cuts greatly into the income, but through Mr. Kenney's care and judgment in matters of this kind the expenses have been held down so that the paper pays its way. Our aim has always been and still is to make this not a great publication, but a simple compendium of compressed air information. We do not aim to reach anything more than this, and as such it has a field of usefulness and value.

Scientific men in this city are deeply interested in the announcement published in one of the leading papers of the discovery by the French chemists, MM. Desgrez and Balthazard, of a process for renewing air indefinitely. As described, the method employed by these chemists completely restores to vitiated air its vital and wholesome quality.

Bioxide or peroxide of sodium is used by the Frenchmen, and they assert that in process of decomposition, presumably at normal temperatures, it gives off oxygen and at the same time absorbs the carbonic acid produced by human breath and the burning of gas. The discoverers assert that by the application of their process divers and others who have to spend time under water or in tunnels or mines, closely packed "sweat shops" and factories, can have pure air created and continually renewed inside of an aluminum helmet, which is coated on the inside with a preparation of the bioxide of sodium.

Dr. R. Ogden Doremus, chemist, of the College of the City of New York, took a great interest in the matter the moment it was brought to his attention, and at once began to make experiments to test the value of the discovery. Our American chemists, however, are not agreed as to the way in which the French chemists have achieved their result.

To make air artificially does not seem a difficult problem, as its component parts are well known. Some years ago efforts of this kind were made and brought to a practical result in the Fleuss apparatus, which carried certain salts in a chamber over the helmet of what resembled a diving apparatus. These salts produced air which was breathed by the person wearing the helmet, and it was claimed that for a limited time this would serve as a useful apparatus for firemen entering smoky rooms. We believe that a serious objection to the Fleuss system was the headache which was produced by breathing this air, but this may be overcome in the new system referred to.

Liquid Air as an Explosive.

Among other peculiar properties of liquid air, says Mr. A. Larsen, in a paper read before the Institution of Mining Engineers, it has been found that in combination with carbonaceous substances it forms an explosive compound, and numerous experiments have been made in different countries with the view of applying it to blasting. The first practical trials were made in a colliery in Germany about three years ago. They do not appear to have been very successful, and were soon abandoned. Since then trials have been made at different places, but the most important of these have been made, and are still being continued, in one of the largest explosive works on the Continent, the carbonate factory at Schlebusch.

Many different mixtures were studied, both as regards explosive strength and safety of manipulation, while Professor Linde endeavored to turn the results so obtained to practical account by getting the system introduced in the Simplon Tunnel. One of the problems to be

studied was to find a suitable carbon carrier. A number of these have been tried, but most of them involve a considerable amount of danger; not only are they highly inflammable after being soaked with liquid air, but when ignited they often detonate immediately and with great violence.

Very good results have lately been obtained with a mixture of equal parts of paraffin and of charcoal. Several modes of preparing the cartridges have been adopted. Either a wrapper was first filled with the carbonaceous material and bodily dipped in liquid air until completely soaked, or the liquid air was poured into the filled wrapper. The liquid air would be taken down into the mine in large "ammunition boxes," the latter preferably on a wheel base, and sent into the different working places, like ordinary empty tubs. Square-shaped wire baskets filled with cartridges would be taken down at the same time, placed in the liquid in due course, and left there. By the time the boxes had arrived at the shot-firing points all the cartridges would be soaked full, but they would, of course, remain in the liquid until immediately before being placed in the shot-holes.

A cartridge 8-in. in length by 2¾-in. in diameter, when filled with a mixture of kieselguhr, tar, and tar oil, weighs 11¾ ozs. The same absorbed 24¾ ozs. of liquid air, thus showing a total weight of 2 lbs. 4½ ozs. The time occupied for fully soaking the cartridges was about 10 minutes. The life of a liquid-air cartridge is unfortunately but ephemeral when once it has been removed from its vital fluid. A cartridge of the above-mentioned dimensions would have to be fired within 15 minutes to avoid a missfire.

A larger cartridge would, of course, have a better chance, but a thinner one much less. Liquid-air cartridges are best detonated with a small gun-cotton primer and detonator. Dynamite primers such as are used for blasting gelatine are useless, as they would immediately freeze. The explosive effect to be derived from liquid-air cartridges depends, therefore, (1) on the "freshness" of the liquid; (2) on the selection of carbonaceous material; and (3) on the time of exposure. This last is, without doubt, the most important consideration, and, besides, the most difficult to adapt to the requirements of practice.

Cartridges of small diameter, such as are met with in ordinary mining, would appear to require quite exceptional working conditions to enable their use with advantage. Even cartridges of large diameters—say, 3-in. to 4-in.—require very quick handling. The rapid surface evaporation soon creates a coating of inert material around the cartridge which, acting like an empty space, causes a considerable loss of pressure. Again, the absorptive power of the carbon carrier, as well as the amount of carbon contained therein, are important factors to consider. A carrier rich in carbon, but of inferior absorbent capacity, will, if the cartridge be exposed too long, leave too much carbon monoxide in the fumes to make it safe for underground work.

Broadly speaking, it may be said that with certain admixtures, notably of the petroleum variety, and by using highly-oxygenated air, it is possible to obtain an explosive compound of greater strength than blasting gelatine. But these mixtures are, as already mentioned, highly inflammable, and therefore dangerous to use. The safer mixtures are less strong. Owing to the rapid evaporation, however, a reliable standard of strength is not obtainable in any case.

Pneumatic Hand Rammer.

The pneumatic hand rammer, illustrated herewith, is designed to meet a large variety of work in the foundry, not only on the floor, but on heavier loam work, where it may be used to good advantage alone or as an auxiliary to the heavier type of pneumatic rammer which is suspended from a crane. This hand rammer is in general design similar to the suspension rammer, but is made light enough so that its use cannot become irksome to the operator. At the same time it is sufficiently heavy so that its inertia absorbs any variation that may arise from the rapid reciprocation of its piston and the rammer head. There are no exposed working parts to this machine, so that dust and dirt cannot affect its operation and durability. The valve mechanism is entirely inclosed, and is as simple as is consistent with proper distribution of air in the cylinder and smooth working. The rammer rod is hexagon in shape, as

shown in the engraving, so that it cannot turn except at the will of the user. It is also arranged so that the piston will remain at the top of its stroke when the machine is stopped. The weight of this rammer is 45 pounds, and it strikes 250 to 300 blows per minute, using air pressure at from 50 to 100 pounds per square inch. Only 15 cubic feet of free air per minute are consumed in continuous operation, as shown in the illustration. The machine is provided with a handle on each side; to the handle on the right side is attached the air supply holes and the admission of air to the cylinder of the rammer is controlled by means of a throttle lever under the thumb of the user; exhaust air passes out through the handle on the opposite side; the speed and force of the blows may be varied at the will of the user. A number of different shaped rammer heads are provided with each machine; they are attached to the rammer rod by means of a taper fit and may be changed in less than one-half minute without letting go of the handles.

The manufacturers of this machine, the Philadelphia Pneumatic Tool Co., of Philadelphia, New York and Boston, are furnishing these machines for a great variety of uses. Besides regular foundry work, it has been found to be unsurpassed as a labor saver in ramming up converter bottoms in Bessemer steel plants, and the rammers have been adopted by a great many of the largest plants of this kind in the country. The rammer has also been found useful in ramming the moulds of special shapes of fire brick for use in glass and other furnaces. On any kind of work where ramming has to be done, it is safe to say that this machine in the hands of an unskilled workman will do the work of from four to six men using the ordinary ramming bar.

Working Rock Drills by Electrically Compressed Air.

In some of the German collieries the drills are worked by compressed air, but the compression takes place within the mine, not far from the face, the air-compressor being driven by an electric motor, taking its current from the regular power service of the collieries. German mining engineers are stated to prefer this plan to either working the drills by compressed air, the air being compressed on the surface, as in England, or to driving the drills by electric motors, and it is stated to be more economical, though no figures are given. In Belgium rock-drilling by electricity has not been attempted.

Pneumatic Hand Rammer

Compressed Air Machinery

Compressed Air.*

Our earliest authentic records of the application of air in a physical or mechanical sense are found in a book by Hero of Alexandria, who lived, so we are informed by historians, from 284 to 221 B. C. Hero is said to have been a student of Ctasibus, who is credited with producing the first pneumatic air gun, and later produced a book on Pneumatics, "Hero's Pneumatics." This was a review of the art up to his time, a remarkable work in which is recorded a variety of pneumatic devices used mostly by the tricky yet shrewd priests to intimidate the ignorant, childlike men of those days into an awed and superstitious obedience. Among these pneumatic appliances, the most of which the author makes no claims to have invented, is one, the Hero Fountain, a simple device quite as familiar to the world as the steam engine. Other early records tell of the primitive efforts of Philo of Byzantium, and the fathers of the early Chaldean Church. But it was only after centuries had rolled by that, so far as we know, any advance was made. To Boyle, a physicist, may be credited the next mile stone in this field of science. Boyle's law, named after its discoverer, and proposed about 1662, sometimes credited to Mariotte, states that at a given temperature the volume of a body of gas varies inversely as the pressure, density and elastic force, and it is this law, verified time and again since then, which forms the foundation of thermodynamics. Dr. Papin is credited with suggesting, in 1700, the use of air for forcing carriers through tubes. 1800 is the year in which the blast furnace is claimed to have been introduced into Wales. Other physicists have added here and there the laws and theories which constitute the science of thermodynamics, and enable us to calculate and predict the probable action of our thermal machines.

Among the many entitled to the most credit the names of Avagardo, Gay Lussac, Torricelli and Regnault stand out most prominently. Another period equally as important but more recent includes the names of Rankine, Carnot, Thurston, De Volson Wood and others who have formulated and collated the scattered facts and developed the laws of thermodynamics into an exact science. So much has been written by those mentioned and dozens of others about the general subject of gases, among which we may include air, that it is hardly possible to impart much that is new except from the practical standpoint; that is, from the point of application of the principles to the actual machines.

To begin with, let us consider air as a material, as it is. In other words, it is a substance, and, it so happens, a composite substance. Its constituents, speaking now of ordinary air, are oxygen, argon, nitrogen, carbonic acid, and a certain amount of water vapor; generally speaking, it is regarded as made up of 23 parts by weight of oxygen and 77 parts by weight of nitrogen, or by volume 21 parts of oxygen and 79 parts of nitrogen. This air surrounds the earth like a shell to a depth of about 20 miles. It varies in density from practically nothing where it shades off into space to that produced by a pressure of 14.7 lbs., which we call "atmospheric pressure."

At 0° C. (32° F.) and atmospheric pressure (14.7 lbs.) one pound of dry air occupies a space of 12.386 cu. ft., and conversely a cu. ft. of air weighs 0.0807 lbs. These figures for an average temperature, say 60°, are 13.089 cu. ft. and 0.0764 pounds per cubic foot. In other words, an increase in temperature with a constant pressure increases the volume of this air. Being a substance it has properties like other substances. It is elastic and can expand or be compressed. This compression may be done in three ways: isothermally, with temperature kept constant by some refrigerating device; adiabatically, in which the temperature is allowed to increase as it will, the containing vessel being protected to keep in the accumulated heat; and a combination of isothermic and adiabatic compression, or the system of compression approached in the best machines of to-day.

Before discussing compressed air in the modern meaning of the term, it is desirable to divide our subject, and this is

*J. J. Swann in The Sibley Journal.

easily done because it naturally falls into three sub-divisions:

1. Production.
2. Transmission.
3. Use.

Or the compression, the transmission and the expansion. Air is not a perfect gas, but it is enough so for our purposes; hence, the laws and formulas used in considering a perfect gas may be applied to it as well.

A perfect gas is one which, when under a constant pressure, will have a rate of expansion exactly equal to the rate at which it absorbs heat; or, a perfect gas is one with which, for each given increment of pressure, there will be an equal increment of heat. Stated as an equation we have

$$(p)_{v\ \mathrm{constant}} \propto t \qquad (v)_{p\ \mathrm{constant}} \propto t$$

$$p\,v \propto t$$

$$\text{or } \frac{p\,v}{t} = \frac{p_1\,v_1}{t_1} = C = \text{(constant)} \qquad (1)$$

in which the prime letters represent a different set of values from p, v and t, which are the initial values for pressure, volume and temperature. Reducing this to 0° Centigrade and considering one cubic foot of dry air at the sea level, we have

$$\frac{p_0 v_0}{t_0} = \frac{14.7 \times 144 \times 12.38}{460.66 + 32} = 53.21$$

$$\text{then } \frac{p\,v}{t} = C. \quad p\,v = 53.21 \times t,$$

or in the metric system,

$$p\,v = 29.20 \times t.$$

This is simply another way of stating Boyle's, or Mariotte's, law of perfect gases, and, while not absolutely true for all gases, it may, for engineering purposes, be employed for the so-called permanent gases, including air.

As already stated, the relations of pressure, volume and temperature may be considered in two ways, isothermally and adiabatically.

Consider for a minute Fig. 1, which represents a cylinder with an area of 1 sq. ft. and a length of about 14 ft. filled with air under atmospheric conditions, say 14.7 lbs. pressure and 60° F. temperature. We will then consider the cylinder surrounded by a refrigerating medium or device capable of absorbing any heat which may be generated above that which is resident in the surrounding air under the atmospheric conditions. If the piston is now advanced, the air is condensed, the molecules have less and less space in which to travel, molecular impacts increase in frequency and the temperature of the whole gas increases, thus giving evidence of the generation of heat. However, if we may use the expression, this surplus of heat is absorbed by the refrigerator as fast as produced, and we have the relation of pressure and volume called for in the equation $p\,v=C$ (constant), which, graphically, is an equilaateral hyperbola asymtotic to the X and Y co-ördinate axes.

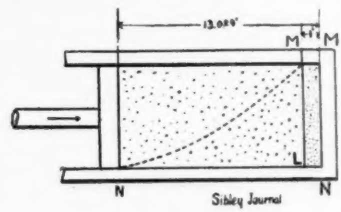

FIG. 1.

Adiabatic compression under the same conditions would be accomplished by substitution for the refrigerator, lagging or packing which would prevent the removal or addition of heat from or to the cylinder.

The advance of the piston, as in the former cases, decreases the space in which the molecules move, hence their movements become more rapid, their minute impacts occur with increased frequency and force, and, as a result, there is an increase in the amount of heat present in the cylinder. This heat causes a positive expansion of the enclosed air, necessitating an application of increased power to move the piston. In other words, other things being equal, adiabatic compression requires the expenditure of more power than isothermal compression. The equation representing this adiabatic compression must then be different from isothermal compression, and it can be shown mathematically that

$$p\,v^{\gamma} = p_1\,v_1^{\gamma} = \text{Constant.} \quad \text{Thus}: D\,H = 0$$

$$C_v\,d\,t = -p\,d\,v$$

$$C_p\,d\,t = v\,d\,p$$

where C_v = specific heat at constant volume
C_p = specific heat at constant pressure

dividing $\frac{dp}{p} = -\frac{C_p}{C_v}\frac{dv}{v} = -\gamma\frac{dv}{v}$

Integrating, $\log\frac{p}{p_1} = \log\left(\frac{v_1}{v}\right)$

When p_1 and v_1 are the initial limits, the other limits being general.

hence, $p\,v^\gamma = p_1\,v_1^\gamma$ = constant

eliminating p by using $p\,v$ = Constant $\times\, t$

$$\frac{t}{t_1} = \left(\frac{v_1}{v}\right)^{\gamma-1} \text{ and } = \left(\frac{p}{p_1}\right)^{\frac{\gamma-1}{\gamma}}$$

These are the equations of adiabatics for a perfect gas in which v, p, t, are initial limits, and v_1, p_1, t_1, other values taken anywhere, or terminal. The term γ is a constant and is the ratio of the specific heats, which are constant for perfect gases. That is,

$$\frac{C_p}{C_v} = \gamma$$

$$\text{for air, } \gamma = \frac{0.2375}{0.1689} = 1.406.$$

It is thus seen that the apparatus which, in compressing from one condition to another, effects the greatest cooling will be the most efficient.

Compression.

To all intents and purposes the compression which we obtain even in the best forms of air compressors is nearly adiabatic, and even if it is not, the considering of it as such is an error on the right side. Such being the case, let us consider the work necessary to compress a cylinder full of air. To start with, we have our cylinder either single or double acting, connected with a receiver or reservoir, the passage to which is closed by a discharge valve. The pressure in this reservoir is something above atmospheric, say P_m: our cylinder is filled with free air under atmospheric conditions. As the piston is advanced towards the closed end the pressure of the enclosed air increases along the curve MN to M, which is the pressure P_m of the receiver. The discharge valve then lifts and the further advance of the piston performs the work of forcing the now compressed air into the receiver against approximately a constant pressure.

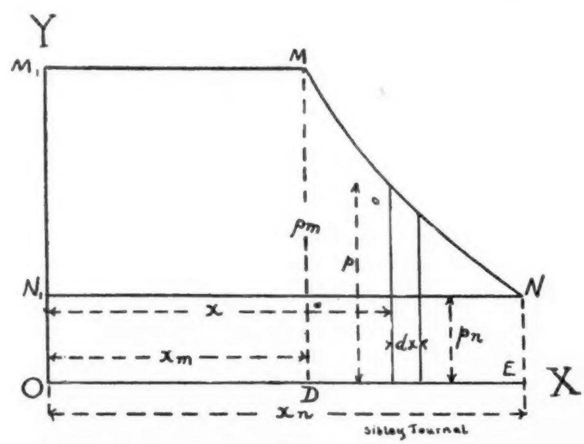

FIG. 2.

We thus have the work done in a complete stroke divided into two portions. That of compression and that of delivery. The piston is, of course, shoved ahead by the piston rod, in turn connected with some form of engine. There is, however, an additional pressure of 15 lbs. per sq. inch assisting, due to the free air entering the inlet valve on the other end of the cylinder. This pressure is balanced, however, by a like pressure at the exit of the receiver.

If, Fig. 2, we let the increasing pressure of the air be p, which at N would be 14.7 lbs., atmospheric pressure, and p_m the receiver pressure, F the piston area, and x the distance from O the piston is at any moment. Then the work done in compression will be represented by the area MNL and that of delivery by the area $M' \, MLN'$.

$$\left\{\begin{array}{c}\text{area}\\ \text{M M L}\\ \text{work of}\\ \text{comp.}\end{array}\right\} = w_1 = -\int_E^D F(p - p_n)\, dx \quad \text{(a)}$$

in which p and x are variable

$$\left\{\begin{array}{c}\text{area M}_1\\ \text{M L N}_1\\ \text{work of}\\ \text{delivery}\end{array}\right\} = w_2 = -\int_D^O F(p_m - p_n)\, d. \quad \text{(b)}$$

in which $p = p_m$ and is constant adding (a) and (b) and simplifying, we have, work per stroke

$$= W = w_1 + w_2 = 3v_m p_m \left\{ 1 - \left(\frac{p_n}{p_m}\right)^{1/3} \right\}^{\dagger} \quad (2)$$

For convenience in approximate calculations the following table will prove of value:

Two-, three-, and poly-stage compression employs exactly the same formulas, introducing however, the condition of inter-cooling. At the end of the compression in the first cylinder the discharge valve opens and the air passes out into the inter-cooler, which is being emptied at the same instant by the air passing into the high pressure cylinder. The cubic dimensions of the cylinder should be such that the compressed charge can pass in and just fill the cylinder, thus preventing any loss of pressure due to expansion.

The work involved in compressing a given weight of air, say one pound, is obtained by assuming pressures and temperature, or by measuring them in the case of an operating engine, and employing the formulas already given. Assume p_1 as our original pressure with an absolute temperature T_1. Let p_c = pressure at end of the first compression. We have the equation already given (in which $n = \gamma$).

$$u_1 = \frac{n}{n-1} R\, T_1 \left[\left(\frac{p_c}{p_1}\right)^{\frac{n-1}{n}} - 1 \right]$$

R is a constant=C. The second stage

HORSE POWER DEVELOPED TO COMPRESS 100 CUBIC FEET OF FREE AIR, FROM ATMOSPHERE TO VARIOUS PRESSURES.

Gauge Pressure Pounds.	One-Stage Compression D. H. P.	Gauge Pressure Pounds.	Two Stage Compression D. H. P.	Four-Stage Compression D. H. P.
10	3.60	60	11.70	10.80
15	5.03	80	13.70	12.50
20	6.28	100	15.40	14.20
25	7.42	200	21.20	18.75
30	8.47	300	24.50	21.80
35	9.42	400	27.70	24.00
40	10.30	500	29.75	25.90
45	11.14	600	31.70	27.50
50	11.90	700	33.50	28.90
55	12.[illegible]7	800	34.90	30.00
60	13.41	900	36.30	31.00
70	14.72	1000	37.80	31.80
80	15.94	1200	39.70	33.30
90	17.06	1600	43.00	35.65
100	18.15	2000	45.50	37.80
		2500		39.06
		3000		40.15

† Church's Mechanics of Engineering, page 637.

starts at p_c and runs to p_2 with a final temperature T_2

$$u_1 = \frac{n}{n-1} R T_1 \left[\left(\frac{p_2}{p_c} \right)^{\frac{n-1}{n}} - 1 \right]$$

Adding, we have,

$$u = (u_1 + u_2) = \frac{n}{n-1} R T_1$$

$$\left[\left(\frac{p_c}{p_1} \right)^{\frac{n-1}{n}} + \left(\frac{p_2}{p_c} \right)^{\frac{n-1}{n}} - 2 \right]$$

To determine the value for p_c which will make the work a minimum we make the first differential equal zero, which gives,

$$p_c = \sqrt{p_1 p_2}$$

and using this value in the above combined equations we get the expression

$$U = \frac{2n}{n-1} R T_1 \left[\left(\frac{p_2}{p_1} \right)^{\frac{n-1}{2n}} - 1 \right]$$

The same process can be employed for three, four or other stages.

Stated differently this formula means that

$$\text{Total work} = \frac{(\text{No. of stages})\, n}{n-1}$$

$$(\text{constant}) \left(\begin{matrix}\text{absolute initial} \\ \text{temperature}\end{matrix} \right)$$

$$\left[\left(\frac{\text{final pressure}}{\text{initial pressure}} \right)^{\frac{n-1}{(\text{no. of stages})\, n}} - 1 \right]$$

It is sometimes desirable to know the mean effective pressure resulting from a given compression. This may be obtained from the formulas

$$\text{Mean effective pressure} \begin{cases} \text{Adiabatic} = \dfrac{n}{n-1} p_1 \left[\left(\dfrac{p_2}{p_1} \right)^{\frac{n-1}{n}} - 1 \right] \\ \text{Isothermal} = p_1 \log_e \dfrac{p_2}{p_1} \end{cases}$$

These are derived by dividing the equations representing the total work of adiabatic compression and delivery of one pound of air by v_1

$$U = \frac{n}{n-1} p_1 v_1 \left[\left(\frac{p_2}{p_1} \right)^{\frac{n-1}{n}} - 1 \right]$$

and

$$U = p_1 v_1 \log_e \left(\frac{p_2}{p_1} \right)$$

In determining the efficiency of compression it is usual to divide the total isothermal work by the total work of adiabatic compression, the initial pressures and temperatures and the final pressures being the same in both cases. This applies to both cases.

For more than one stage the numerator remains the same, the denominator alone changing to correspond with the proper number of stages.

The temperature (absolute) at the end of the compression is found from the formula

$$\frac{p_m}{p_n} = \left(\frac{T_m}{T_n} \right)^3$$

$$T_m = T_n \left(\frac{p_m}{p_n} \right)^{1/3}$$

The air at the temperature, T_m, passes to the reservoir or into the transmission mains, where it loses heat by conduction and radiation until it reaches a final temperature, T_n. During this cooling the volume has decreased, but the pressure has been maintained by air constantly being forced into main by the compressor, which keeps the density, γ, constant. The mechanical equivalent of the heat lost in this cooling is lost work and naturally reduces the efficiency of the machine.

To-day the range through which compressed air is used calls for pressures from as low as 10 pounds, as in the case of pneumatic tubular dispatch, to as high as 3,000 pounds, which is the maximum pressure used for street railway work. However, by far the greatest field is found between 50 to 1,000 pounds.

For convenience we may sub-divide the production of compressed air into three pressures.

1 Low	from 5 to	50 pounds.
2 Medium	from 50 to	500 pounds.
3 High	from 500 to	5000 pounds.

The first of these finds its most extensive use in blast furnace operation, for which purpose the engines are nearly all of the vertical slow speed Corliss type, with large air cylinders.

This first class is almost universally of the single compression type; that is, all the compression is done in one cylinder. The second or medium class includes by all odds the greater portion of air machinery used at the present time. In it are all the compressors operating coal cutters, rock drills and machine tools of every sort, such as hammers, chippers,

riveters, etc. In this class single and double or compound compression is customary.

With pressures above about 100 pounds compounding is necessary, both as a matter of economy and for safety. The term compounding is here mentioned for the first time and calls for an explanation.

When we compress air only as high as 100 pounds in a single cylinder without cooling, that is, adiabatically, temperatures ranging from 475° to 550° F. are reached. In other words, the cylinder walls and working parts are hot enough to melt ordinary solder, or as hot as steam between 950 pounds and 1,000 pounds pressure. With this temperature the greatest difficulty is experienced in lubricating the cylinders and valves, owing to the valves and passages becoming clogged with a thick gummy substance, or a coke-like material. This is really burnt oil, easily explained when we remember that the flash point of the most staple cylinder oils is not over 450° F., and is on an average nearer 425°. In addition to the inconvenience and loss of efficiency due to clogged discharge ports and pipes, and the heat and annoyance and increased wear due to the hot parts, there is a real and considerable danger from explosions, which result from the formation of an explosive mixture of vaporized oil and compressed air. In the early days of compressed air several unfortunate accidents resulted from disregard of this heat of compression.

In a compound compressor, that is, one in which the air is partially compressed in one cylinder, then transferred to a second cylinder and the compression continued to the maximum, the opportunity for cooling the air and preventing this increase of temperature is doubled because the cylinder surface is twice as great as in the first case, and also an opportunity is afforded to pass the air through what is called an inter-cooler, which is a form of reservoir designed to bring the air which passes through it into intimate contact with cooling surfaces, which are continually cooled by running water.

HEAT PRODUCED BY THE COMPRESSION OF AIR.

Atmospheres.	Pounds per sq. in. above a vacuum.	Pounds per sq. in. above atmosphere gage pressure.	Volume in cu. ft.	Temperature of air throughout the process, degrees F.	Total increase of temperature degrees F.
	Pressure	*Pressure*			
1.00	14.7	0.00	1,000	60.0	00.0
1.10	16.17	1.47	.9346	74.6	14.6
1.25	18.37	3.67	.8536	94.8	34.8
1.50	22.05	7.35	.7501	124.9	64.9
1.75	25.81	11.11	.6724	151.6	91.6
2.00	29.40	14.70	.6117	175.6	115.8
2.50	36.70	22.00	.5221	218.3	158.3
3.00	44.10	29.40	.4588	255.1	195.1
3.50	51.40	36.70	.4113	287.8	227.8
4.00	58.80	44.10	.3741	317.4	257.4
5.00	73.50	58.80	.3194	369.4	309.4
6.00	88.20	73.50	.2806	414.5	354.5
7.00	102.90	88.20	.2516	454.5	394.5
8.00	117.60	102.90	.2288	490.6	430.6
9.00	132.30	117.60	.2105	523.7	463.4
10.00	147.00	132.30	.1953	554.0	494.0
15.00	220.50	205.80	.1465	681.0	621.0
20.00	294.00	279.30	.1195	781.0	721.0
25.00	367.50	352.80	.1020	864.0	804.0

Assuming, again, a compression of 100 pounds. If we draw air into the first cylinder at atmospheric pressure and temperature and compress it to about 30 pounds, the resulting temperature is from 200° to 260°, according to the effectiveness of the cooling jackets of the cylinder. If the air then is passed through an intercooler of sufficient capacity, the temperature is reduced to practically that of the intake, and possibly something lower, say 70 degrees; it then passes on to the second cylinder, quite cool, and at a pressure of 30 pounds. In this cylinder it is raised to 100 pounds, and here again the temperature increase will be only from 200° to 250°, which is too low to cause any inconvenience.

the jacketed parts. Air is a bad conductor of heat and takes time to change its temperature. The piston, while pushing the air toward the head, rapidly drives it away from the jacketed surfaces, so that little or no cooling takes place. This is especially true of large cylinders, where the economy effected by water jackets is considerably less than in small cylinders. Leaks through the valves or past the piston will explain many isothermal cards, and until something better than a water jacket is devised it is well to seek economy in air compression through compounding.

In the case of high pressures such as those indicated in the third class, that is, from 500 to 5,000 pounds, it is essential to

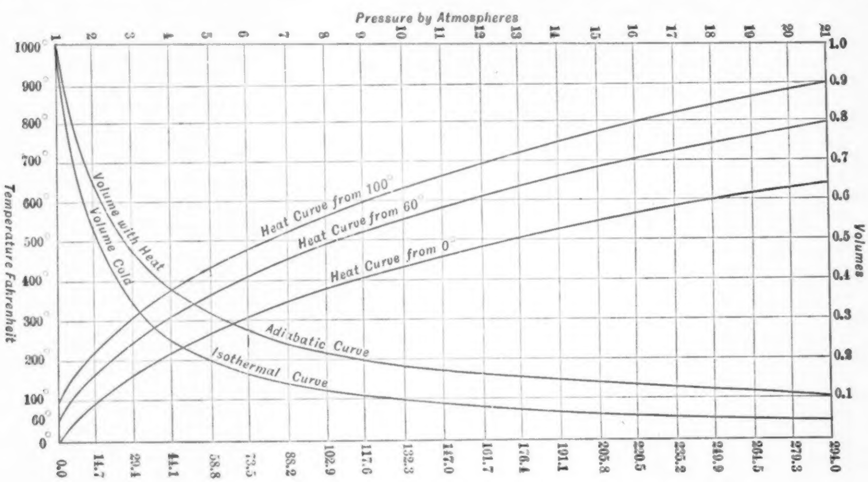

FIG. 3.—SAUNDERS' CURVES.‡

Compounding, however, does not result in any material economy, unless the air is thoroughly cooled between the stages. Hot air in the cylinder of an air compressor means a reduction in the efficiency of the machine, because there is not sufficient time during the stroke to cool thoroughly by any available means. Water jacketing, the generally accepted practice, does not by any means effect thorough cooling. The air in the cylinder is so large in volume that but a fraction of its surface is brought in contact with

employ three or four stages; the same general process is employed as in the compounding, there being first, second and third compressions, and first, second and third intermediate inter-coolers. This arrangement makes it possible to deliver air under these high pressures at a temperature even less than that of the atmos phere. Of course, there is quite a range between summer and winter conditions, and these have their effect; but the ad vantages of stage compression are facts. It has been found that a difference of 5° at the inlet valve causes a variation of about 1 per cent. in the efficiency, and the

‡W. L. Saunders. "Compressed Air Production."

curves shown afford an idea of the increased work brought about by a slight increase in initial temperature.

The four stage compressors are used for charging mine locomotives, for power transmission and for such special apparatus as charging of pneumatic street cars, etc.

The following table will serve to illustrate the large saving that it is possible to effect by compounding. From it the percentage of work lost by the heat of compression, taking isothermal compression, or compression without heat, as a base, can be obtained for pressures from 60 to 2,000 pounds:

INCREASED EFFICIENCY RESULTING FROM STAGE COMPRESSION.
"COMPRESSED AIR."

Gauge Pressures.	One Stage.		Two Stage.		Four Stage.	
	% of work lost in terms of Isothermal Compression.	% of work lost in terms of Adiabatic Compression.	% of work lost in terms of Isothermal Compression.	% of work lost in terms of Adiabatic Compression.	% of work lost in terms of Isothermal Compression.	% of work lost in terms of Adiabatic Compression.
60	30. %	23. %	13.38%	11.8 %	4.65%	4.45%
80	34.	25.26	15.12	13.12	5.04	4.80
100	38.	27.58	17.10	14.62	8.00	7.41
200	52.35	34.40	23.20	18.88	9.01	8.27
400	68.60	40.75	29.70	22.90	12.40	11.04
600	83.75	44.60	32.65	24.60	15.06	13.10
800	90.	47.40	35.80	26.33	16.74	14.32
1000	96.80	49.20	39.00	28.10	16.90	14.45
1200	106.15	51.60	40.00	28.60	17.45	14.85
1400	108.	52.	41.60	29.4	17.70	15.00
1600	110.	53.3	42.90	30.0	18.40	15.54
1800	116.80	54.	44.40	30.6	19.12	16.05
2000	121.70	54.8	44.60	30.8	20.09	6.65

In the above figures no account is taken of jacket cooling, as it is well known among pneumatic engineers that water jackets, especially cylinder jackets, though useful, and perhaps indispensable, are, as just explained, inefficient, especially so in large compressors. The two and four stage figures in this table (columns 3 and 4) are based on reduction to atmospheric temperature, 60° Fahrenheit, between stages. This is an important condition, and in order to effect it much depends on the inter-cooler, and a rule which might be observed to advantage among engineers is to specify that the manufacturers should supply a compressor with coolers provided with one square foot of tube cooling surface for every 10 cu. ft. of free air furnished by the compressor when running at its normal speed.

The table shows that when air is compressed to 100 lbs. pressure per sq. in. in a single stage compressor, without cooling, the heat loss may be 38 per cent. This condition, of course, does not exist in practice, except, perhaps, at exceedingly high speeds, as there will be some absorption of heat by the exposed parts of the machine. It is safe, however, to say that in large compressors that compress in a single stage up to 100 lbs. gauge pressure, the heat loss is 30 per cent. This, as shown in the table, may be cut down more than one-half by compounding or compressing in two-stages, and with three-stages this loss is brought down to 8 per cent., theoretically, and perhaps to 3 per cent. or 5 per cent. in practice.

A great deal of time and attention have been devoted to coolers and *inter-coolers* by the larger manufacturers of air compressors, and the most successful form

now employed resembles a surface steam condenser. In this, speaking now of the "Sergeant" type, the heated air, direct from compressors, passes into an upper opening, and down between a large number of small tinned copper tubes, held vertically in a sort of chimney. The air finally emerges into the shell portion of the inter-cooler and is free to travel through the top to the outlet tube. The smaller tubes mentioned terminate at either end in plates, into which they are

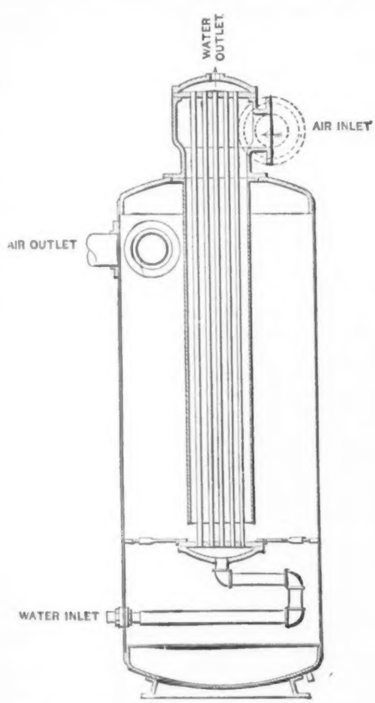

FIG. 4.—THE SERGEANT INTERCOOLER.

expanded. The cooling water enters through the lower pipe and is forced upwards through the cooler tubes, and finally emerges at the water outlet at the top. The water tubes are set so close together that they divide the incoming stream of air into thin sheets and bring it into very intimate contact with the cooling surface. As stated, the air is caused to enter at the top and pass downward, while the cooling water enters at the bottom and passes upward. This is the accumulating principle upon which all successful liquid air apparatus have been constructed.

A properly designed inter-cooler should reduce the temperature of the compressed air to its original point; that is, to the temperature of the intake air. It can do even more than this, especially in winter, when the water used in the inter-cooler is of low temperature. A simple coil of pipe submerged in water is not an effective inter-cooler, because the air passes through the coil too rapidly to be cooled in the core, and such inter-coolers do not sufficiently split up the air to enable it to be cooled rapidly. This splitting up of air is an important point. A nest of tubes carrying water and arranged as described, so that the air is forced between and around the tubes, is an important point in an efficient form of inter-cooler. If the tubes are close enough together and are kept cold, the air *must* split up into thin sheets while passing through. Such devices are naturally expensive; but first cost is a small item when compared with the efficiency of the compressor, measured in the coal and water consumed.

Receiver-Intercoolers are more efficient than those of the common type, because the air is given more time to pass through the cooling stages, and because of the freedom from wire drawing which may take place in intercoolers of small volumetric capacity.

Aftercoolers are in some installations as important as intercoolers. An aftercooler serves to reduce the temperature of the air after the final compression. In doing this it serves as a dryer, reducing the temperature of air to the dew point, thus abstracting moisture before the air is started on its journey. In cold weather, with air pipes laid over the ground, an aftercooler may prevent accumulation of frost in the interior walls of the pipes, for where the hot compressed air is allowed to cool gradually, the walls of the pipe in cold weather act like a surface condenser, and moisture may be deposited on the inside for the same reason that we have frost on the inner side of a window pane. In using these aftercoolers, and also intercoolers, it is good practice to allow from 8 to 10 cu. ft. of free air per minute for each square foot of cooling surface. Further, an allowance of 1 lb. of water for each 2 cu. ft. of free air should be made.

Makeshift aftercoolers are frequently employed, such as abandoned boilers, sections of large pipe, which are placed outdoors and provided with a drain and relief valve. These serve in special cases, but for ordinary practice it pays to use a standard aftercooler. The use of an aftercooler cannot be too strongly recommended, as it will be the means of avoiding many of the ills usually laid at the door of the compressing apparatus.

The heat given out or wasted in this cooling down to receiver temperature may be represented by the equation

$$Q = C_p (T_1 - T_2)$$

or, by substitution,

$$T_2 = \left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}} T_1$$

$$Q = C_p \left[\left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}} - 1\right] T_1$$

which, when translated into ordinary language, means that the quantity of heat, (Q) equals the specific heat at a constant pressure, times the absolute initial temperature, multiplied by an expression made up of the quotient of final pressure divided by the initial pressure raised to the $\frac{n-1}{n}$ power, from which 1 is subtracted, n being an exponential occurring in the equation of compression $p v^n = C$ (constant), and will depend upon the degree of perfectness of cooling during compression, ranging from 1 for isothermal compression to 1.414 in the case of adiabatic.

In selecting an air compressor, the conditions under which it is to operate must be carefully considered, as it is impossible to design a single compressor which will fit all conditions. The most important factors are: pressure desired, the character of apparatus to be operated, the cost of fuel, allowable space and quantity of air required. Generally speaking, economy has not been the most important consideration until recently. Where a large volume of air is required and the character of the work is fairly constant, so that the demands upon the compressor are not varying to too great an extent, and where the cost of fuel makes it desirable to produce the air at a small cost, it has been found by experience that at a fairly low speed, compound Corliss engine gives the best results. In such plants as may be termed permanent, a compressor using a compound Corliss engine, running condensing, with compound air cylinders (the air being intercooled and also aftercooled), will be found to transfer the mechanical power to available air power most economically. For coal mining and places where the service is intermittent, fuel is cheap and the service of a skilled engineer is not desirable, it has been found that a "straight-line" single acting compressor best meets the conditions.

In compressed air practice, as in engine or boiler practice, it is well to install a larger machine than is needed at the time, because it invariably happens that the demand increases, and compressors, in common with other apparatus, work best under designed conditions.

All forms of compressor engines in which enrgy is used to compress air, can be sub-divided into rotary compressors, such as blowers and fans used for large volume low pressure work, and reciprocating compressors following in form the conventional steam engine design. That is, a horizontal or vertical cylinder, piston, cross head, connecting rod, crank and fly wheel. These may again be sub-divided into those driven by steam, or driven by water power, belts of one sort or another, or motor driven, either direct or geared. It is this general class of air, or, for that matter gas, compressors which has slowly but surely made for itself a name, and has developed into one of the large American industries.

The three classes into which reciprocating apparatus for the production of compressed air naturally fall, and considerations of convenience, first cost and economy of operation, have resulted in the development of certain distinct types of compressors, which may be classed under the general heading of self-contained, steam actuated compressors, and those operated by some external means.

Both classes may be simple, duplex or poly-compression machines. Experience, however, has sifted out the best forms, which are as follows:

Steam Actuated.

(1). Straight Line; that is, steam and air cylinders in one line, mounted on a continuous girder frame. A self-contained, reliable type; a great user of steam, but a most satisfactory type where

fuel is inexpensive and where a large amount of air is not needed. Usually single stage compressors, but often built in two or three stages.

(2). Duplex. Usually built with two parallel engines, connected by 90° cranks to a single flywheel shaft, with air cylinders behind each steam cylinder. Both steam and air cylinders are the same diameter. This type makes no great pretense at economy, but finds an extensive field in locations where fuel is not high and where simplicity and small first cost are important, and where considerable air or high pressures are desired.

(3). Compound. Of the same general character as the duplex, except that either or both air and steam cylinders are compounded. In some cases the engine may be run condensing. This is, however, hardly necessary, except for very large sizes, where it is far more desirable to use the last class, or Corliss type.

(4). Corliss Type. As implied in the name, this class includes compressors in which the engine portion employs the well-known Corliss valve motion. Such compressors, with few exceptions, are of the horizontal type, the air cylinder or cylinders, as the case may be, being placed tandem to the steam cylinders. They are employed where the volume of air desired and the fuel conditions demand the most economical form of engine. They are usually componded, both for steam and air, and usually run condensing.

Air Brakes

Tests of Steeet Car Brakes by the New York Railroad Commission.

The most important and exhaustive series of tests of street car brakes ever undertaken was made last year by the New York Railroad Commission; and their results have just been made public in a pamphlet of 60 pages, accompanied by plates showing the autographic records taken during the tests. Copies of this pamphlet can be obtained, we presume, by addressing the office of the New York Railroad Commission at Albany. In the present article we shall attempt to summarize the main results reached by these tests, and the most important lessons to be drawn from them.

These tests, which were briefly described in this journal while they were in progress, were made on the Lenox avenue line of the Metropolitan Street Ry. Co. in New York city. The track chosen for the test has a very slight grade (8.8 ft. per mile), and is laid with 90-lb. girder rails with 2-in. head. The line is a double track one, operated by the electric underground conduit system. The cars used were the Metropolitan company's standard 8-wheel cars, weighing 20,816 lbs., equipped with Brill "maximum traction" trucks, with 30-in and 20-in. wheels, and a total wheel-base of 17 ft. 6 ins. Brake shoes were applied to all wheels.

There were 26 applications by brake manufacturers and inventors to take part in the tests; and 16 companies actually equipped cars and had their apparatus tried. Of these, 4 were air brakes, 4 electric, 3 hand-power, 2 friction, and 2 were combined track and wheel brakes. The different brakes are described as follows in the official report:

Air Brakes.

The reliability of the air brake has been thoroughly established by its use on steam roads. A large number of them are now used on electric cars, and, with proper inspection and care, the air brake, as applied to electric cars, is a reliable, powerful, quick and easily controlled means of applying the braking power to a car wheel. Four systems of air brakes were submitted and tested. All were similar, so far as relates to the use of air under compression in a cylinder to operate a piston from which, through levers, the power was transmitted to the brake shoes. They differed in the method of compressing the air and applying it to the piston.

The G. P. Magann Air Brake Co. presented what is known as a storage air system, in which there is an air compressor and reservoir located at the powerhouse or some central point on the street car system. . This reservoir is charged with air usually compressed to 300 lbs. pressure. The car is equipped with two storage reservoirs, which are charged in a few seconds from the stationary reservoir at 300 lbs. pressure.

By means of a reducing valve this pressure is reduced to 50 lbs., at which pressure the air enters an auxiliary reservoir, from which it is controlled, to the brake cylinder by means of the engineer's valve, in the usual manner. There are some special features in the construction and operation of this valve. The storage equipment of cars is calculated for 300 stops, which is sufficient for ordinary car operation; when necessary this capacity can be increased.

The Christensen Engineering Co. presented what is known as the straight-air system, which consists of a reservoir, an electric motor compressor, an automatic regulator which governs the operation of the motor compressor; an engineer's valve and the usual brake cylinder. In this system, as its name implies, the compressed air passes direct from the reservoir to the brake cylinder, there being no auxiliary reservoirs or reducing valves bteween the pressure reservoir and the brake cylinder. All of this apparatus, with the exception of the controller, is placed under the car. There are a number of special features in the construction and operation of the system as presented by this company.

The Standard Air Brake Co. presented an automatic air brake system, consisting of an electric motor-driven compressor, a storage-pressure reservoir, a motor controller, brake cylinder and engineer's valve. This system is similar to the one described above, except that there are a number of special features in construction and operation in which the two systems differ; the general principle of compressing and applying the air is, however, the same.

John E. Reyburn presented an air brake system similar to the two last described, except that the compressor was operated mechanically instead of by an electric motor. This compressor was worked by the motion of the car axle, which was transferred to the compressor by means of friction disks, or wheels, one of which revolved with the axle, the other being fast on the compressor shaft. These were placed in such position that they made a firm frictional contact. These friction disks are thrown into contact and released by compressed air from the reservoir. After the air has been compressed in the cylinder, the operation is the same as usual in air brake systems.

—Engineering News.

Liquid Air

One of the greatest difficulties to be contended with in the practical application of liquid air is that of keeping it for a length of time. According to Mr. Carl Linde, small quantities may be preserved in well-exhausted and silvered double-walled glass vessels for a relatively long time. One litre of liquid air requires for its evaporation in such a vessel about fourteen days. The ordinary sheet iron vessels used industrially, holding about fifty litres, and covered with felt or wool, allow about two litres to evaporate hourly. Experiments are being made with a view of building large double-walled and silvered sheet-iron holders, and we may expect that holders will be constructed in which the evaporation will be not more than 1 per cent. per hour.

Air Jets

Inasmuch as it has been called to our notice that a large number of users and prospective users of pneumatic tools are under the impression that suit has been entered against us by one of our competitors for infringement of their patents on account of the fact that they have brought suit against various pneumatic tool companies, we wish to notify the trade in general through your publication that we are not involved in any way, shape or manner in the present litigation, as our "Little Giant" pneumatic tools are fully covered by patents,

the validity of which is not questioned by any one.

We are enclosing you herewith a circular, which is self-explanatory.

Your very truly,

Standard Pneumatic Tool Co.,

By A. B. Holmes.

The circular referred to is as follows:

We wish to notify all our customers and the trade in general, that in the patent litigation entered into between the Chicago Pneumatic Tool Company, Joseph Boyer, the Standard Pneumatic Tool Company and the Chouteau Manufacturing Company, all suits have been dismissed by the advice of their respective attorneys, they recognizing that the Boyer and Chouteau patents cover the fundamental principles of all pneumatic hammers, without the combined use of which no successful pneumatic hammer can be made.

Recognizing the value of their respective claims, they have purchased licenses from each other covering their present style of hammers.

We consider this action necessary for the protection of users of our respective tools.

Chicago Pneumatic Tool Company,

By J. W. Duntley, President,

Standard Pneumatic Tool Company.

By Edward N. Hurley, President.

We have received from the Chicago Pneumatic Tool Company a copy of the special edition catalogue which they issued for the "Master Mechanics and Master Car Builders' Convention," which was held at Saratoga Springs in June. This catalogue is very tastefully gotten up, is printed on heavy paper, and contains 32 pages, in which are illustrated a portion of the extensive line of pneumatic labor saving appliances manufactured by this company.

The Chicago Pneumatic Tool Company has engaged Mr. Fred F. Bennett as sales agent and manager of advertising, with headquarters at the main office of the Company, Monadnock Block, Chicago. Mr. Bennett resigned a position as sales agent for the American Steel Casting Company and American Coupler Company, of Chester, Pa., the change taking effect July 1st. Mr. Bennett seems to be peculiarly adapted to his present position. His apprenticeship of several years was served on the Chicago daily papers as reporter and city editor, and later he was city editor of the Omaha Republican. Subsequent to this he was for many years Western representative of the Railroad Gazette of New York.

The large dynamo and feeder switches of the Niagara Falls Power Plant, each controlling current to the extent of 5,000 H. P., are operated by cylinders to which compressed air is admitted. Air is far superior to any other agent, steam being out of the question in a purely hydraulic plant and not being well adapted; hydraulic pressure adjacent to electric apparatus being dangerous because of risk of burn outs from dampness and leakages, etc. Air is used also for cleaning out the generators and removing dust. Compressed Air stands on guard over this most powerful electric installation, ready to act instantly, insuring immediate switching in case of short circuiting, and avoiding damage at other points.

COMMUNICATIONS.

Under this heading will be published inquiries addressed to the Editor of COMPRESSED AIR. We wish to encourage our readers in the practice of making inquiries and expressing opinions.

We request that the rules governing such correspondence will be observed, viz., all communications should be written on one side of the paper only; they should be short and to the point.

Fieldhome, N. Y., Aug. 8, 1900.

"Compressed Air,"

Gentlemen:—At dinner we were discussing the utility of the windmill, and as far as any of us knew, the storage battery and reservoir of water seemed the only methods of turning a fitful into a

regular power. How expensive would it be to store compressed air? In forcing air through a heating apparatus would it save coal if the compressed air was not cooled? The usual windmills seem to develop from one to three horse power.

C. De P. Field.

The expense of storing compressed air will depend upon the volume and pressure per square inch.

During compression air should be kept as cool as possible. Any increase in temperature after compression would have a tendency to increase its efficiency providing heat was retained until the work was done.

By compound compression you can compress six cubic feet of free air to 100 lbs. pressure with 1 H. P.

If properly applied six cubic feet of free air at 100 lbs. pressure will produce about ¾ H. P. One cubic foot storage capacity will contain 7.8 cubic feet free air at 100 lbs. pressure.

I am not acquainted with the storage battery.

So. Norwalk, Conn., Aug. 25, 1900.

"Compressed Air":

Your July issue describes a Worthington pump with a re-heater device and refers to the apparatus as a novelty.

This device was patented by me 19 years ago—U. S. Patent No. 244,603.

The claims recite among other things:

"First, the method of expanding or increasing the effective force or power of the air in a pumping engine driven by compressed air by utilizing the heat of the water acted upon by the pump as herein before set forth.

"Second, the combination of a compound air motor pumping engine and an interheater to be supplied with water from the pump as and for the purposes herein before set forth."

The device is good, but as you see from the above, not new.

E. Hill, Gen. Manager,
Norwalk Iron Works.

PATENTS GRANTED JULY, 1900.

Specially prepared for COMPRESSED AIR.

647,883.—COMPRESSOR FOR AIR, ETC. Henry C. Sergeant, Westfield, N. J., assignor to The Ingersoll-Sergeant Drill Company, New York, N. Y. Filed July 6, 1899. Serial No. 722,918.

The combination in a compound compressors, of cylinders and pistons for successive compressions, a water-box in which said cylinders and their valves are contained, a cooler consisting of a plurality of coils of pipe arranged in said water-box, a discharge-pipe from the first or low-pressure cylinder having a plurality of branches communicating with said coils at one end of each, a chamber of communication common to the other ends of the several coils and a valved communication between the said chamber and the high-pressure cylinder, substantially as herein described.

652,960.—PNEUMATIC CONVEYER. Melvin J. Foyer, Chicago, Ill. Filed Oct. 9, 1899. Serial No. 733,071.

A pneumatic conveying apparatus, the combination of a low-pressure pipe, means for maintaining a reduction of pressure therein, a conveying-tube connected toward its delivery end with said low-pressure pipe, a door at the despatching end of said tube controlling the admission of atmospheric pressure thereto, an electromagnet for holding said door open during the admission of air, an electric circuit for said magnet, and a circuit-breaker in said circuit in the vicinity of the delivery end of said tube and provided with a movable part located in the path of the carrier and serving when moved by the carrier to deënergize the magnet and permit the door to close.

652,983.—AIR-HOIST. George F. Steedman, St. Louis, Mo. Filed June 12, 1899. Serial No. 720,191.

A pneumatic hoist, the combination with the cylinder and its piston, of a valve-casing, a disk valve operating therein, a port controlled by said disk valve, and a stem on which said valve is mounted, said stem being formed with an exhaust-passage.

A pneumatic hoist, the combination with the cylinder and its piston, of a valve for admitting and exhausting pressure to and from said cylinder, and means capable of being clamped to the piston at different points for operating said valve to admit or exhaust pressure to and from the cylinder to compensate for an increase or decrease in the load carried by the piston, said means comprising a spring-actuated lever arranged on the valve-stem, a rod for operating said lever, a collar to which said rod is connected, and a clamping-screw in said collar.

653,044.—AUTOMATIC SWITCH FOR PNEUMATIC CARRIERS. Fred R. Taisey, Indianapolis, Ind. Filed July 10, 1899. Serial No. 723,337.

A pneumatic carrier, the combination with the main tube, of switch-tubes leading

therefrom, switch-tongues for deflecting the carrier-boxes from the main tube into the switch-tubes, trigger mechanisms for operating said switch-tongues that extend into the passage-way to the main tube, and a series of carrier-boxes having centrally located pins graduated in length to operate said trigger mechanisms.

In a pneumatic carrier, the combination with the main tube, of switch-tubes leading therefrom, switch-tongues for deflecting the carrier-boxes from the main tube into switch-tubes, a series of trigger mechanisms for operating such switch-tongues that extend into the passage-way to the main tube and provided with actuating-pawls graduatingly arranged in series, and a series of carrier-boxes having centrally-located pins graduated in length to operate such pawls.

653,094.—HYDRAULIC AIR-COMPRESSOR. Daniel Kirkman, Philadelphia, Pa. Filed Dec. 23, 1899. Serial No. 741,420

A hydraulic air-compressor in which are combined a vessel having a valved outlet for compressed air, a valved inlet and a valved outlet for water, an air-pressure relief and inlet valve or valves, and means for operating the same, a water-outlet valve-stem having a float for lifting the same, a support for holding the water-outlet valve in the open position, and float mechanism for withdrawing said support as the water falls in the vessel.

654,511. — WATER-FEEDING AND AIR-COMPRESSING MECHANISM FOR MOTOR-VEHICLES. William R. Bowker and Frank P. Sherman, Waltham, Mass. Filed Nov. 24, 1899. Serial No. 738,216.

The combination, with the main steam-boiler and water-tank, of a steam feed-water pump deriving steam from said boiler, a discharge-pipe leading from the pump to the boiler, an inlet-pipe connecting the pump with the tank, and provided with a valve and a supply-pipe connected to the said inlet-pipe and provided with a valve.

In a motor-vehicle, the combination with a steam feed-water pump, of an air-compressing pump, a lever connecting the piston-rods of the two pumps and having a hinged section separately connected to one of said piston-rods; substantially as described.

In a motor-vehicle, the combination with a steam feed-water pump, of an air compressing pump operatively connected therewith, a compressed-air reservoir having a valved connection with the air-pump, and an auxiliary valved pipe leading from the air-pump; substantially as described.

In a motor-vehicle, the combination with a steam feed-water pump, of an air-compressing pump operatively connected therewith, a compressed-air cylinder having a valved connection with the air-pump, and also having a valved connection with a brake-cylinder.

654,690.—PNEUMATIC-DESPATCH TUBE. William Townsend, Champaign, Ill., assignor to Truman W. Miller, Chicago, Ill.; Harriet B. Miller and Felix Babbage, executors of said Truman W. Miller, deceased. Filed Sept. 14, 1899. Serial No. 730,467.

A composite structure to serve as a terminal of a pneumatic-despatch system, composed of separable parts or elements, said elements being so formed, proportioned and provided with uniting and carrier guiding and controlling parts that they may be assembled together in different relations to vary the completed form of the terminal.

654,764. — PNEUMATIC WATER-ELEVATOR. Marion N. Schauffleberger, Bristol, Va., assignor of one-third to John W. Bolton, same place. Filed July 8, 1899. Serial No. 723,233.

A duplex pneumatic water-elevator, the combination with the tank divided by a central partition into two compartments, each having an inlet-opening in the bottom provided with a valve, the outlet-pipes, the exhaust-pipes, the pivoted arms provided with valves, the rods pivoted thereto and the floats, of the housing at the upper part of the tank, the air-pipe communicating therewith, the pivoted lever having a valve at each end, the air-pipe with which said valves engage, the rods connected with said lever passing through said air-pipes, and the bars connected therewith having slots at the lower ends through which said pivoted arms pass.